EXD.

VOL. 85. Part 4. Pp. 131–140, 3 pls. 1st May, 1936.

IMP. INST. ENT.
— LIBRARY —
1 MAY 1936
En. 344
ERIAL

THE

TRANSACTIONS

OF THE

ROYAL ENTOMOLOGICAL SOCIETY

OF

LONDON

Experiments to test the efficiency of protective adaptations in insects.
By Robert Carrick, B.Sc. . . . . pp. 131–140

LONDON:
PUBLISHED BY THE SOCIETY AND
SOLD AT ITS ROOMS, 41, QUEEN'S GATE, S.W. 7

[*Price 3s. 6d.*]

THE ROYAL ENTOMOLOGICAL SOCIETY OF LONDON

Founded, 1833. Incorporated by Royal Charter, 1885.

PATRON—HIS MAJESTY THE KING.

OFFICERS and COUNCIL for the SESSION 1936-1937.

A. D. Imms, Sc.D., M.A., F.R.S., *President.*

Prof. P. A. Buxton, M.A.
H. Willoughby Ellis
S. A. Neave, O.B.E., M.A., D.Sc. } *Vice-Presidents.*

Francis Hemming, C.B.E., *Treasurer.*

A. W. McKenny-Hughes, D.I.C., *Secretary.*

F. J. Griffin, A.L.A., *Registrar.*

Council.

R. B. Benson, M.A.
Prof. G. D. Hale Carpenter, M.B.E. D.M.
C. L. Collenette.
Brig.-Gen. B. H. Cooke, C.M.G., C.B.E., D.S.O.
H. Eltringham, M.A., D.Sc., F.R.S.
G. Fox-Wilson.
L. G. Higgins, M.A., F.R.C.S.
J. A. Simes, O.B.E.
W. H. T. Tams.
W. H. Thorpe, M.A., Ph.D.
C. B. Williams, M.A., Sc.D.

Finance and House Committee.

C. B. Williams, M.A., Sc.D. (Chairman).

Prof. P. A. Buxton, M.A.
C. L. Collenette.
C. N. Hawkins.
R. W. Lloyd.
O. W. Richards, M.A.
W. H. Thorpe, M.A., Ph.D.

Publication Committee.

W. H. T. Tams (Chairman).

H. E. Andrewes.
Prof. G. D. Hale Carpenter, M.B.E., D.M.
F. W. Edwards, M.A., Sc.D.
H. Eltringham, M.A., D.Sc., F.R.S.
O. W. Richards, M.A., D.Sc.
V. B. Wigglesworth, M.A., B.Ch., M.D.

Library Committee.

L. G. Higgins, M.A., F.R.C.S. (Chairman).

K. G. Blair, D.Sc.
E. A. Cockayne, M.A., M.B., F.R.C.P.
B. M. Hobby, M.A., D.Ph.
K. Jordan, Ph.D., F.R.S.
R. W. Lloyd.
H. Scott, M.A., Sc.D.

Committee for the Protection of British Insects.

Rt. Hon. Lord Rothschild, D.Sc., F.R.S. (Chairman).

Capt. E. Bagwell-Purefoy, F.Z.S.
C. L. Collenette.
W. J. Dow.
J. C. F. Fryer, O.B.E., M.A.
Col. F. A. Labouchere.
N. D. Riley, F.Z.S.
W. G. Sheldon, F.Z.S.
H. M. Edelsten (Secretary).

The Executive Officers are *ex officio* members of all Committees.

TRANSACTIONS AND PROCEEDINGS OF THE SOCIETY.

Some of the early volumes of the Society's Transactions are out of print. Any single volume of the years 1868–1887, is sold at 10*s.* to Fellows. The volumes for 1868–1900, in sets of not less than five, as well as the five of the Third Series (1862–1867), may be obtained by Fellows at greatly reduced prices on application to the Secretary. The following is a price list of recently published parts—

1934.—Transactions, Vol. LXXXII: Part I, £1 10*s.* 0*d.*, to Fellows, £1 2*s.* 6*d.*; Part II, £2 8*s.* 0*d.*, to Fellows, £1 16*s.* 0*d.*

Proceedings, Vol. IX: Part I, 4*s.* 0*d.*, to Fellows, 3*s.* 0*d.*; Part II, 6*s.* 0*d.*, to Fellows, 4*s.* 6*d.*; Part III, 12*s.* 0*d.*, to Fellows, 9*s.* 0*d.*

1935.—Transactions, Vol. LXXXIII: Part I, £2 12*s.* 0*d.*, to Fellows, £1 19*s.* 0*d.*; Part II, £1 10*s.* 0*d.*, to Fellows, £1 2*s.* 6*d.*; Part III, £1 13*s.* 0*d.*, to Fellows, £1 4*s.* 9*d.*; Part IV, £1 10*s.* 0*d.*, to Fellows, £1 2*s.* 6*d.*

Proceedings, Vol. X: Part I, 10*s.* 6*d.*, to Fellows, 7*s.* 9*d.*; Part II, 10*s.* 6*d.*, to Fellows, 7*s.* 9*d.*

STYLOPS.

1932–5.—Vols. 1–4, £1 16*s.* 0*d.* each; to Fellows, £1 7*s.* 0*d.*

Proceedings Series B. Taxonomy (being the continuation of *Stylops*).

1936.—Vol. 5, subscription £1 4*s.* 0*d.*

EXPERIMENTS TO TEST THE EFFICIENCY OF PROTECTIVE ADAPTATIONS IN INSECTS

By Robert Carrick, B.Sc.

(Dept. of Zoology, University of Glasgow.)

Communicated by Sir Edward Poulton, F.R.S.

[Read 20th November, 1935.]

With Plates 1 to 3.

Contents.

		PAGE
I.	Introduction	131
II.	The predators	132
III.	The prey	132
IV.	The experiments	134
	1. Procryptic resemblance.	
	2. Aposematic coloration.	
	3. Mimetic resemblance.	
V.	Conclusions	139

I. Introduction.

The present controversy between supporters of "selective" and "proportional" predation, which implies belief or otherwise in the idea that the course of evolutionary change is moulded by the forces of natural selection, seems to call for carefully planned experiments to provide data in favour of one view or the other. The unattainable ideal would be to have a detailed knowledge of numbers and species of food available to predators under natural conditions, over a wide area, and for a long period of time. The numbers of accepted species being known, the proportions of these to the unaccepted are interpreted in the light of the food-types to which the various species belong—aposematic, procryptic, or neutral—and the issue is settled. It is obvious that if accepted food has alone been examined, and the total possible food supply is mere conjecture, then the conclusion reached can only be regarded as a probability. If stomach content analysis shows two per cent. aposematic prey as against ninety-eight per cent. other prey, the conclusion that the predators have a marked dislike for aposematic species is based on the assumption that these latter form far more than two per cent. of the individuals which predators can see and obtain with ease. The examination of stomach contents is far from valueless, but at the best it provides strong circumstantial evidence and not conclusive proof. Imposing lists of food-species tell only a half-truth, and in this connection some accurate observations of habit may be just as valuable.

Dr. F. Morton Jones' paper (1932, *Trans. ent. Soc. Lond.*, **80** : 345–386) stands out as the fullest attempt to decide relative acceptability of prey in the field, and it is concerned almost entirely with adult Coleoptera, Lepidoptera, and Hemiptera as offered to avian predators. This memoir, together with Dr. H. N. Kluijver's results of food-collecting experiments with young

starlings,* has suggested further experiments designed to test the insect-food-preferences, if any, of various British species of birds at a time when they are feeding their nestlings.

In an investigation of predation which aims at being as nearly true to natural conditions as any controlled experiments on this subject can be, insectivorous birds are in several ways a suitable choice of predator. Their possible insect prey, as it exists in the actual feeding-grounds, can be procured quite easily for experimental purposes; an accurate watch may be kept on all their actions throughout a feeding experiment; and the nesting habit can be utilised in two ways—the observer knows an exact spot to which the bird must return, and he has an area defined for him—moderate in size with most small insectivorous species—to which the parent restricts its feeding activities. He is thus able to offer known selections of the bird's own available food and to study the result at close quarters. Furthermore, he is assured that the bird is actively hunting for food almost all day during the nesting period.

My aim has been to conduct experiments in the field, which will be as natural as possible, the predator having a free choice to select such prey as it fancies or to ignore it altogether. The smaller insectivorous birds feed their young mainly on a diet of Diptera and larval Lepidoptera, and therefore the types of prey used in the following experiments are these in addition to aposematic Hymenoptera. Possible criticisms of these experiments are that the prey is necessarily fixed so that its powers of escape by movement are prevented, and that it is being offered in greater concentration than is normal in nature. These objections are not fatal to this investigation, for if the theories of protective adaptations are sound the animals so protected rely on them and not on mobility; and the crowding together of more procryptic individuals than is natural tends to lessen their protective efficiency because of the numbers themselves and also owing to an increased probability of disturbance causing movement.

II. The Predators.

Four species of British insectivorous birds have filled the rôle of predator :—

Wren (*Troglodytes t. troglodytes* L.) . . .	5 young; nest in river bank.
Whitethroat (*Sylvia c. communis* Latham) . .	5 young; nest in long grass.
Willow-Warbler (*Phylloscopus t. trochilus* L.)	6 young; nest in long grass.
Sedge-Warbler (*Acrocephalus schoenobaenus* L.) .	5 young; nest I in sedge. 6 young; nest II in grass.

The first three nests were found together in the same small valley at Balmore,† and the feeding habitat consisted of hawthorn, elm, and other trees, broom and rose bushes, and long grass. The Sedge-Warblers nested in willow copses at Possil † and collected food in the willows, dense grasses and sedges around the nest. When a nest had been located it was watched for some time to make sure that the particular birds were confiding enough to feed naturally from trays and branches near the nest, and not to be disturbed by an observer fairly close at hand.

III. The Prey.

The species of prey offered are listed in Table I, and the colour group of each (*vide* Prof. Hale Carpenter, *Trans. ent. Soc. Lond.*, **1921** : 1–105) is added, together with the number of individuals offered and accepted.

* " Bijdrage tot de Biologie en de Ecologie van den Spreeuw (*Sturnus vulgaris* L.) gedurende zijn voortplantingstijd." 1933, *Versl. Meded. PlantenZiekt. Dienst Wageningen*," **69**, 146 pp.

† Possil Loch is a nature sanctuary N. of Glasgow; Balmore is 5 miles further N.

TABLE I.

Classification.	Appearance (length, in mm., and colours, etc.).	Colour group.	Times offered.	Times accepted.
Lepidoptera. Larvae.				
PAPILIONIDAE.				
Pieris rapae L.	22, green.	P	6	6
Gonepteryx rhamni, L.	28, green.	P	13	12
NYMPHALIDAE.				
Aglais urticae L.	30, black and spiny.	A	30	1
	14, early instar, brown, very short hairs.	C	6	6
GEOMETRIDAE.				
Selenia bilunaria Esp.	25, brown, twig-like, " in situ."	PP	21	3
	not " in situ."	P	8	5
Lycia hirtaria Cl.	50, brown, twig-like, " in situ."	PP	22	4
	not " in situ."	C	12	7
ARCTIIDAE.				
Hipocrita jacobaeae L.	28, banded black and yellow.	AA	8	0
NOCTUIDAE.				
Taeniocampa gothica L.	30, green.	P	18	15
Unidentified " loopers."	20, green.	P	8	6
Diptera.				
TIPULIDAE.				
Tipula oleracea L.	26, grey.	C	3	2
Tipula sp. ?	26, light brown.	C	2	2
LEPTIDAE.				
Leptis scolopacea L.	12, grey, brown and black.	C	7	7
CORDYLURIDAE.				
Scatophaga stercoraria L.	10, dull yellow and brown.	C	11	10
SYRPHIDAE.				
Syrphus ribesii L.	11, brown, black and yellow, wasp-like.	AA	5	0
S. bifasciatus Fabr.	9, bronze, brown and yellow, wasp-like.	AA	2	0
S. lunulatus Mg.	9, bronze, brown and yellow, wasp-like.	AA	6	3
Eristalis tenax L.	13, brown and yellow, hairy and bee-like.	AA	3	1
Rhingia campestris Mg.	11, dark and light brown.	C	1	1
MUSCIDAE.				
Morellia simplex Löw.	8, black and grey.	P	5	5
Polietes lardaria Fabr.	12, black and grey.	P	5	4
Mydaea pagana Fabr.	9, dull yellow and brown.	C	3	3
TACHINIDAE.				
Lucilia caesar L.	6, bronze.	A	2	1
Hymenoptera.				
BOMBIDAE.				
Bombus terrestris L.	20, black and orange, hairy.	AA	13	0
B. muscorum L.	20, black with orange pubescence.	AA	3	0
ANDRENIDAE.				
Andrena rosae Panz.	13, dark brown with light brown hairs.	AA	12	1
VESPIDAE.				
**Vespa vulgaris* L.	20, black and yellow.	AA	5	0
TENTHREDINIDAE.				
Strongylogaster lineata Christ.	10, black, and little yellow.	AA	1	0
Trichiocampus viminalis Fall.	10, greenish-yellow and brown.	A	3	0

* *V. vulgaris* is by far the most abundant " common wasp " around Glasgow where I collected, and three out of the five in the table were determined as this species. It is possible, although very improbable, that two may have belonged to one or more of the other superficially similar wasps occurring in the area. Of these *Vespa sylvestris* Scop., which is not uncommon, is more likely to have been employed than any other species except *vulgaris*.

A summarised quotation from Prof. Carpenter's paper, page 50, will make the method of colour grouping clear.

Group symbol.	*Type of insects.*
AA	"Typically aposematic insects of bold and fearless manner, showing conspicuous colours freely exposed."
A	Similar to above, but less conspicuous.
C	Neutral types, which cannot readily be classified as aposematic or procryptic.
P	Insects with "dingy colours or a general resemblance to surroundings."
PP	"Typically procryptic insects, concealed by their extreme degree of resemblance to the colours, and often shape, of their immediate surroundings. Attitude often plays an important part in increasing the resemblance."

It will be obvious that procryptic insects pinned to a feeding-tray or placed on a plant which they do not resemble are *ipso facto* removed from the colour group PP.

IV. The Experiments.

The experiments were designed with the purpose of testing the efficiency of three types of adaptation: procryptic resemblance to surroundings, aposematic or warning colours possessed by distasteful species, and mimetic resemblance to the latter, possessed by palatable species or synaposematic unpalatable species.

1. *Procryptic resemblance.* The efficiency of this adaptation was tested by means of the brown twig-like caterpillars of *Selenia bilunaria* (Early Thorn Moth) and *Lycia hirtaria* (Brindled Beauty). The specimens were bought, but any doubt as to their acceptability was removed at once when they were offered pinned to a feeding-tray. The caterpillar feeds at night and during the day assumes the resting attitude shown in Plate 1, the body sloping out from the twig and a thread passing from the mouth to the support to take the strain. It remains quite motionless unless disturbed. A branch of the food-plant with numbers of these larvae was placed near the nest in such a position as to provide a suitable perch for the parent birds on their way to feed the young. In some experiments, for purposes of control, the same larva was pinned conspicuously on a board near the nest or placed on a different branch. Green larvae of *Gonepteryx rhamni* (Brimstone Butterfly), *Taeniocampa gothica* (Hebrew Character) and smaller geometers were also offered.

The essential data from the five experiments on procryptic resemblance are given below. The experiments are numbered in chronological order, and the colour group is indicated for each species.

Experiment I (Plates 1 and 2), 9.vi.34.

Wren.	
11.25 a.m.	4 green geometer larvae and 1 *S. bilunaria* pinned on tray—P. 4 *S. bilunaria* in procryptic attitude on hawthorn twig—PP.
11.30 a.m.	First visit. Took 2 geometers and 1 *S. bilunaria* from tray (*cf.* Plate 2).
11.32 a.m.	Second visit. Perched on branch beside *S. bilunaria*, but took nothing.
11.35–12.27 p.m.	Eight visits. Three times on hawthorn, but took nothing.
12.34 p.m.	Eleventh visit. 1 *S. bilunaria* was moving and was taken.
12.41–12.56 p.m.	Three visits. Once on hawthorn, but took nothing.

Results: *S. bilunaria* larvae are readily eaten when seen. Procryptic resemblance and habit enabled three to escape being attacked even when the wren perched within reach of them and had just accepted one from the tray. Movement at once proved fatal to one of them.

Experiment VII, 14.vi.34.

Whitethroat.

10.10 a.m.	7 *S. bilunaria* larvae on hawthorn—PP. 6 *G. rhamni* larvae on alder spray—P.
10.16–10.41 a.m.	The birds perched four times on the hawthorn and took no larvae; and five times on the alder and took 4 larvae.
11.0 a.m.	4 *S. bilunaria* were added to the alder and allowed to settle down—P.
11.6–11.38 a.m.	The birds perched six times on the hawthorn and took nothing; and seven times on the alder and took 2 *G. rhamni* and 2 *S. bilunaria*.
11.48 a.m.	7 *S. bilunaria* were recovered from hawthorn and 2 from alder.

Results: The procryptic larvae escaped completely when resting on the branch they resembled, but two out of four were taken when resting in less similar surroundings.

Experiments IX and X, 16.vi.34.

Willow-Warbler.

1.12 p.m.	5 *S. bilunaria* on hawthorn—PP. 5 *G. rhamni* on alder—P.
1.25 p.m.	Five visits had been paid, and 4 *G. rhamni* larvae were taken, and no *S. bilunaria*.
1.35 p.m.	5 *S. bilunaria* larvae were left on hawthorn—PP. 2 *G. rhamni* and 2 green "loopers" were placed beside them—P. 1 *S. bilunaria* was added to alder—P.
1.46 p.m.	Five visits were paid. 4 green larvae and 2 *S. bilunaria* were taken from hawthorn, and the last *G. rhamni* larva was taken from alder.

Results: Experiments IX and X confirm I and VII, and furthermore show that when green larvae attracted the birds to the hawthorn, two *S. bilunaria* larvae were taken. The possibility of the procryptic larvae being touched and caused to move was greatly increased.

Experiment XV, 5.vii.34.

Sedge-Warbler II.

This experiment was conducted on a rather larger scale than any previous one; the nest was situated in grass and herbage rising to a foot from marshy ground, and two branches of elm and hawthorn, placed over the nest and rising to three feet above it, were at once used as perches by the birds. Twenty-two *L. hirtaria* larvae were placed on the elm, and fifteen *T. gothica* larvae on the hawthorn. To the eye, the brown twig-like caterpillars of the former species were very inconspicuous, and the green larvae of *T. gothica* were moderately so. In addition, three nettles bearing seventeen *A. urticae* (Small Tortoiseshell) larvae were placed against the elm and hawthorn; these black spiny larvae were very conspicuous and active but did not wander from the food-plant except in one possible instance. (When larvae have been starved for a day or so previous to an experiment they are more likely to remain on the food-plant during the course of the experiment.)

10.10 a.m.	22 *L. hirtaria* on elm—PP. 15 *T. gothica* on hawthorn—P. 17 *A. urticae* on nettle—A. Eight visits were paid, birds perching on the elm five times and on the hawthorn three times. Two larvae were taken from the hawthorn.
10.30 a.m.	22 *L. hirtaria*, 13 *T. gothica*, and 17 *A. urticae*. Seven more visits; three to the elm, one larva being taken, and three to the hawthorn, 3 larvae being taken.
11.0 a.m.	21 *L. hirtaria*, 10 *T. gothica*, and 17 *A. urticae*. Ten more visits; six to elm, taking 1 larva; six to hawthorn, taking 5 larvae.
11.25 a.m.	20 *L. hirtaria*, 5 *T. gothica*, 17 *A. urticae*. Seven more visits; five to elm, taking 2 larvae; three to hawthorn, taking 2 larvae.
11.40 a.m.	There were recovered 18 *L. hirtaria*, 3 *T. gothica*, and 16 *A. urticae*; probably one of the last had wandered.

Results: During 1½ hours two Sedge-Warblers feeding young perched thirty-four times close to procryptic, not very procryptic, and aposematic larvae. They accepted and fed the young with four out of twenty-two procryptic larvae available, twelve out of fifteen non-procryptic, and none out of seventeen aposematic.

Feeding-tray Experiment XVI which immediately followed this one showed that *L. hirtaria* larvae were quite as acceptable as *T. gothica*, hence it must be concluded that the more procryptic type is enabled to escape predation in its natural surroundings. Also, the aposematic larvae were ignored by the predators in both Experiments XV and XVI.

2. *Aposematic coloration.* The protective value of the aposematic adaptation was tested by offering to the birds mixtures of insect food-types on feeding-trays close to the nests. In the experiments described below a mixture of aposematic and neutral-coloured species was offered. Bees and wasps were chiefly employed for the warning-coloured distasteful types, and brown and grey Diptera, often seen to form part of the natural food, were used as palatable species. As has been said, the specimens were all netted in the vicinity of the nests at which they were offered. They were pinned alive by their wings to the tray, from which the bird picked them up with perfect confidence. Every action of the bird was watched through binoculars.

Experiment II, 9.vi.34.

Wren.

1.35 p.m. 9 insects: 3 *Tipula oleracea*—C.
3 *Leptis scolopacea*—C.
2 *Bombus terrestris*—AA.
1 *B. muscorum*—AA.

2.25 p.m. Eleven visits had been paid to the nest and there remained: 1 *T. oleracea*; 2 *B. terrestris*; 1 *B. muscorum*.

Experiment III, 11.vi.34.

Wren.

9.56 a.m. 8 insects: 2 *Tipula* sp.—C.
3 *Leptis scolopacea*—C.
2 *Bombus muscorum*—AA.
1 *Andrena rosae*—AA.

10.19 a.m. There remained: 2 *B. muscorum*.

Experiment IV, 11.vi.34.

Wren.

10.34 a.m. 12 insects: 3 *Scatophaga stercoraria*—C.
1 *Leptis scolopacea*—C.
2 *Morellia simplex*—P.
1 *Lucilia caesar*—A.
4 *Bombus terrestris*—AA.
1 *Andrena rosae*—AA.

10.59 a.m. Seven visits were paid, and there remained: 1 *S. stercoraria*; 4 *B. terrestris*; 1 *A. rosae*.

Experiment V, 11.vi.34.

Wren.

11.37 a.m. 11 insects: 3 *Scatophaga stercoraria*—C.
1 *Rhingia campestris*—C.
1 *Morellia simplex*—P.
1 *Lucilia caesar*.—A.
3 *Bombus terrestris*—AA.
2 *Andrena rosae*—AA.

2.26 p.m. 8 visits; remained: 1 *L. caesar*; 3 *B. terrestris*; 2 *A. rosae*.

Experiment VIII, 16.vi.34.

Willow-Warbler.

12.13 p.m. 10 lepidopterous larvae : 6 *Aglais urticae* (small)—C.
2 *Selenia bilunaria*—P.
2 unidentified green geometers—P.

12.46 p.m. None remained.

Experiment XIV, 27.vi.34.

Sedge-Warbler I.

4.50 p.m. 10 insects : 2 *Mydaea pagana*—C.
3 *Polietes lardaria*—P.
1 *Bombus terrestris*—AA.
3 *Andrena rosae*—AA.
1 *Vespa vulgaris* *—AA.

5.35 p.m. Eight visits; remained : 1 *P. lardaria* ; 1 *B. terrestris* ; 2 *A. rosae* ; 1 *V. vulgaris.*

Note : When the specimen of *A. rosae* was taken the bird hopped about the bush near the nest for some time and eventually dropped the bee and commenced to sing loudly. It had all the appearance of having been stung, and did not again visit the tray.

Experiment XVI, 5.vii.34.

Sedge-Warbler II.

12.25 p.m. 42 lepidopterous larvae, equal numbers of supposedly edible and distasteful types :
12 *Lycia hirtaria*—C.
3 *Taeniocampa gothica*—P.
6 *Pieris rapae*—P.
13 *Aglais urticae*—A.
8 *Hipocrita jacobeae*—AA.

1.30 p.m. Remained : 5 *L. hirtaria* ; 12 *A. urticae* ; 8 *H. jacobeae.*

3. *Mimetic resemblance.* The degree of protection which a mimetic appearance may confer on a palatable synaposematic species is much more difficult to determine by experiment than the two preceding adaptations. Black-and-yellow banded SYRPHIDAE were offered together with other food-types in the feeding-tray experiments described below, care being taken to include distasteful Hymenoptera similar to the flies used.

Experiment VI, 11.vi.34.

Wren.

12.45 p.m. 14 insects : 1 *Eristalis tenax*—AA.
2 *Syrphus bifasciatus*—AA.
1 *S. lunulatus*—AA.
2 *S. ribesii*—AA.
2 *Bombus terrestris*—AA.
2 *Andrena rosae*—AA.
1 *Vespa vulgaris*—AA.
1 *Strongylogaster cingulatus*—AA.
2 *Trichiocampus viminalis*—A.

1.22 p.m. All remained, except 1 *S. lunulatus.*

* See footnote on p. 133 with reference to this record and the four others in Expts. VI, XI, XII, and XIII.

Experiment XI (*cf.* pl. 3, fig. 1), 27.vi.34.

Sedge-Warbler I.

12.25 p.m. 9 insects : 2 *Scatophaga stercoraria*—C.
2 *Morellia simplex*—P.
2 *Syrphus lunulatus*—AA.
2 *S. ribesii*—AA.
1 *Vespa vulgaris*—AA.

12.50 p.m. Remained : 1 *S. lunulatus* ; 2 *S. ribesii* ; 1 *V. vulgaris*.

Experiment XII, 27.vi.34.

Sedge-Warbler I.

1.5 p.m. 9 insects : 3 *Scatophaga stercoraria*—C.
1 *Mydaea pagana*—C.
2 *Polietes lardaria*—P.
1 *Syrphus lunulatus*—AA.
1 *S. ribesii*—AA.
1 *Vespa vulgaris*—AA.

1.40 p.m. Remained : 1 *S. ribesii* ; 1 *V. vulgaris*.

Experiment XIII, 27.vi.34.

Sedge-Warbler I.

4.5 p.m. 10 insects : 2 *Eristalis tenax*—AA.
2 *Syrphus lunulatus*—AA.
1 *Bombus terrestris*—AA.
3 *Andrena rosae*—AA.
1 *Vespa vulgaris*—AA.
1 *Trichiocampus viminalis*—A.

4.45 p.m. All remained, except 1 *E. tenax*.

Summary of Results.

TABLE II.

Experiment.	PP.		P.		C.		A.		AA.	
	Offered.	Accepted.	Offered.	Accepted.	Offered.	Accepted.	Offered.	Accepted.	Offered.	Accepted.
I	4	1	5	3						
II					6	5			3	0
III					5	5			3	1
IV			2	2	4	3	1	1	5	0
V			1	1	4	4	1	0	5	0
VI							2	0	12	1
VII	7	0	10	8						
VIII			4	4	6	6				
IX	5	0	5	4						
X	5	2	5	4						
XI			2	2	2	2			5	1
XII			2	2	4	4			3	1
XIII							1	0	9	1
XIV			3	2	2	2			5	0
XV	22	4	15	12			17	0		
XVI			9	9	12	7	13	1	8	0
Total . .	43	7	63	53	45	38	35	2	58	5
Percentage accepted .	16·3		84·1		84·4		5·7		8·6	

V. Conclusions.

From these experiments with insectivorous birds it is possible to draw conclusions probably applicable to predation in general.

1. Predation was not proportional, but highly selective. The predator was influenced far more by the nature of the food available than by the relative numbers of different types. Here, however, approximately equal numbers of aposematic (A and AA) and neutral (P and C) individuals were offered; in the former case 7·2 per cent. (7 out of 93) were taken, four of these being Syrphidae, and in the latter 84·3 per cent. (91 out of 108) were accepted. The conditions of experiment were such that the predator had an equal opportunity of choosing either class of prey.

2. Detailed procryptic resemblances were successful as a means of escaping predation, but movement at once destroyed their protective value. It was noticed repeatedly that it was the moving insect which first attracted the attention of the bird.

Two conclusions reached by R. T. Young (1916, *J. exp. Zool.* **20** : 457–499) after a long series of experiments on protective coloration are worth quoting here :

" 1. Protective resemblance is effective in protecting motionless animals from attacks by caged birds.

2. Stillness is probably a more important factor than color in protecting animals from their foes."

Mimetic resemblance was apparently protective, but without further experiments it is not possible to determine how far the results were due to Batesian (pseudaposematic) or Müllerian (synaposematic) resemblance. Four out of sixteen aposematic Syrphidae were taken.

I am much indebted to Dr. H. B. Cott for his continued interest and helpful guidance in the conduct of the experiments, and to Professor Sir E. B. Poulton for many useful criticisms of the manuscript.

Explanation of Plates 1–3.

Reproduced from photographs taken during the experiments.

Plate 1.

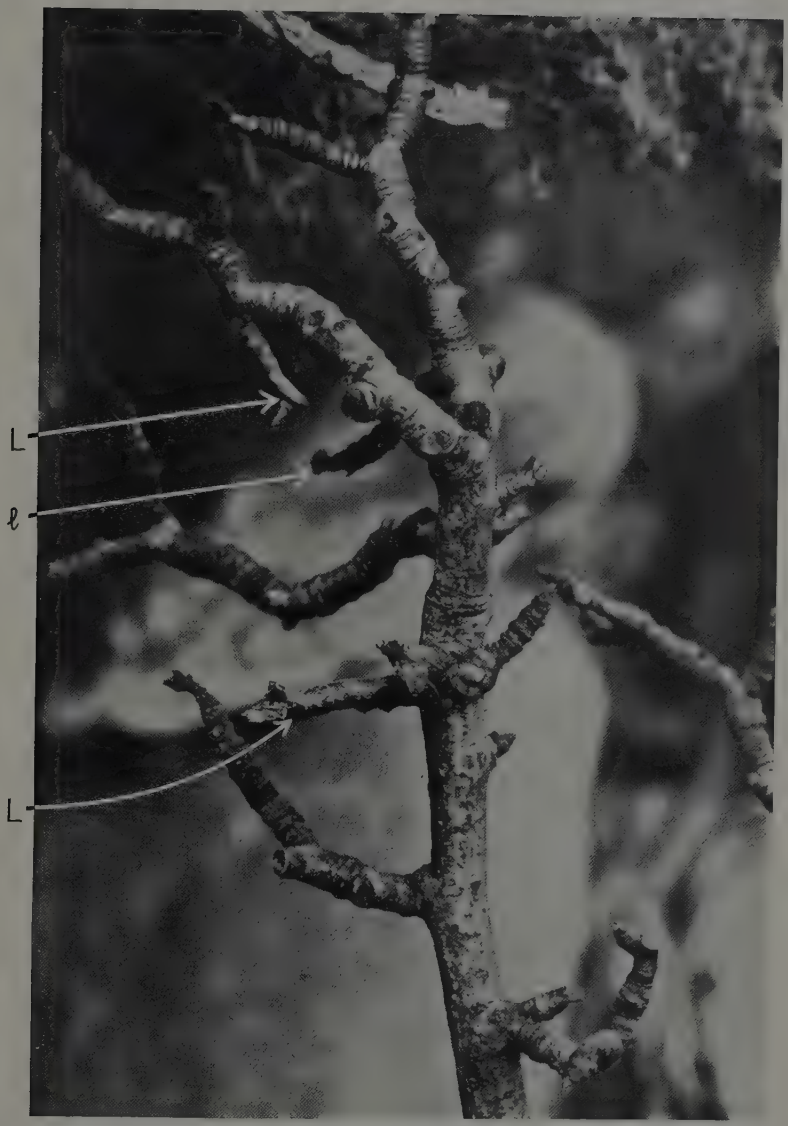
Expt. I. Two larvae (L) of *Selenia bilunaria* in resting attitude on twig of hawthorn at nest of Common Wren. Of the four larvae on the branch one did not come into the photograph while another is almost certainly represented, out of focus, at (l).

Plate 2.

Expt. I. On the left the Wren is shown on the hawthorn twig bearing four *bilunaria* larvae including the two marked (L) on Plate 1, but invisible in the photograph here reproduced. On the right the Wren is seen about to pick up a *bilunaria* larva from the feeding-tray.

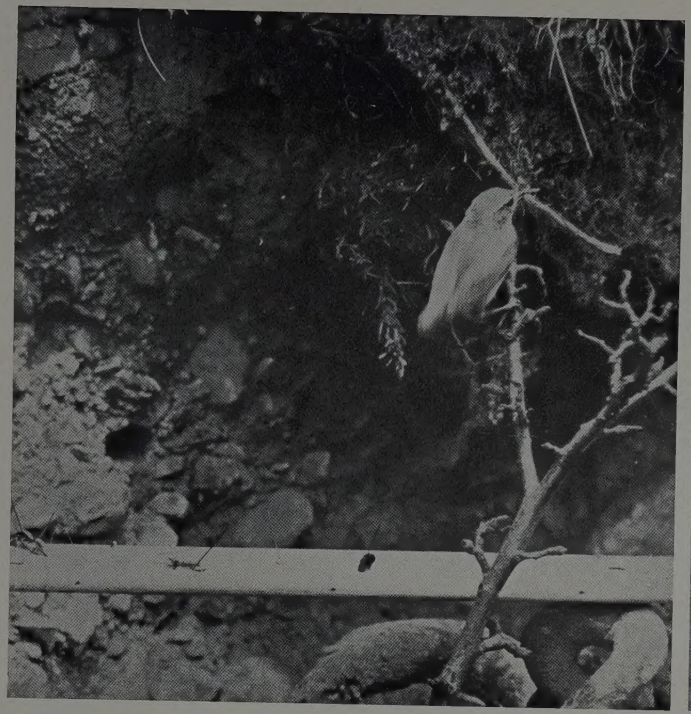
Plate 3.

Expt. XI. Nest and feeding-tray of Sedge-Warbler I.
XVI. Larvae of *Aglais urticae* on nettle.

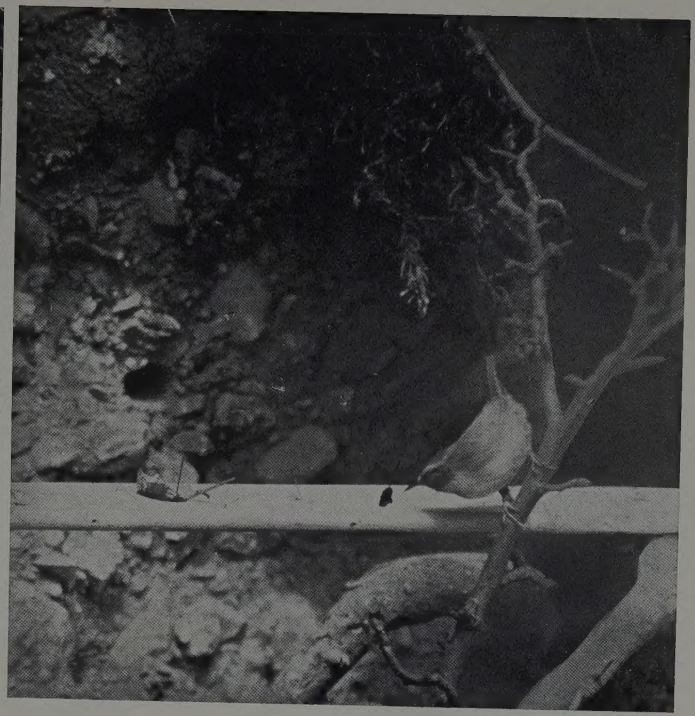


ENGRAVED BY STAR ILLUSTRATION WORKS, LONDON.

Two *S. bilunaria* larvæ (L) and one indistinct (l), on hawthorn twig at Wren's nest. Experiment I.



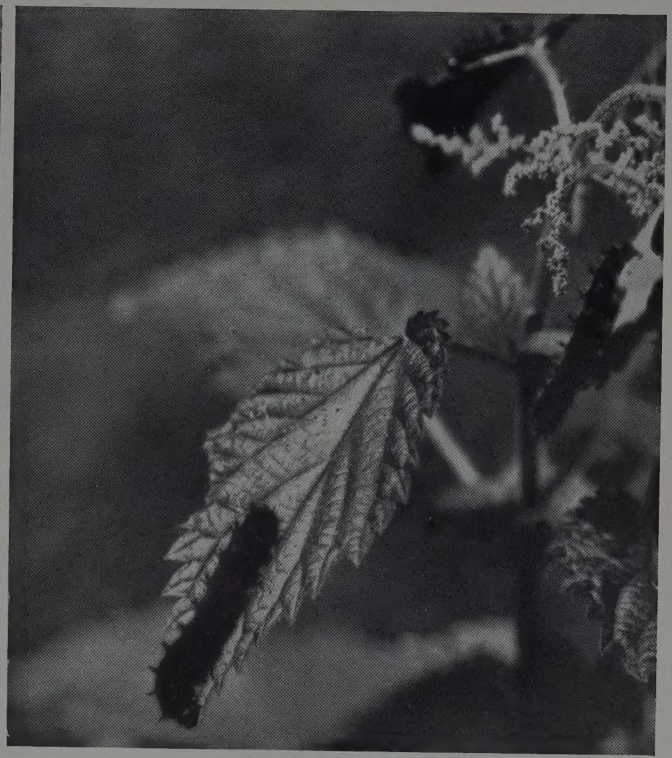
Wren on Hawthorn Twig : larvæ invisible. Experiment I.



ENGRAVED BY STAR ILLUSTRATION WORKS, LONDON.

Wren about to take a larva of *S. bilunaria* from tray. Experiment I.

Nest and tray of Sedge Warbler I. Experiment XI.



ENGRAVED BY STAR ILLUSTRATION WORKS, LONDON.

Larvæ of *A. urticae* on nettle. Experiment XVI.